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EFFECT OF pH ON NICKEL ION RELEASE FROM STAINLESS STEEL CROWNS: AN IN VITRO STUDY

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ABSTRACT

Background: Release of heavy metals from stainless steel crowns, used in pediatric dentistry can cause allergic reactions. Among these metals, nickel is known to be a common cause of contact allergy and hypersensitivity reactions.

Aim: Assessment of nickel ion release from stainless steel crowns at different pH levels of artificial saliva.

Methods: In this in vitro study nickel ion release from 45 stainless steel crowns of 3M ESPE company in artificial saliva of pH 4.3, 5.5 and 6.3 was analyzed. Concentration of nickel ion in artificial saliva was estimated using atomic absorption spectrometry. Statistical analysis was performed using one way analysis of variance and Spearman's rank order correlation.

Results: Significantly higher amount of nickel ion release was observed at pH 4.3 than pH 5.5 and 6.3. pH of artificial saliva was inversely related with nickel ion release.

Conclusion: Nickel ion release from stainless steel crowns increases with decrease in pH.

KEYWORDS: Stainless steel crown, nickel, ion release, pH

Introduction:

Prefabricated stainless steel crowns (SSCs) are one of the most common dental devices containing stainless steel used in children (Keinan et al., 2010). The chemical composition of contemporary prefabricated SSC is similar to many orthodontic bands and wires (Randall, 2002; Menek et al., 2012), containing 65-73% iron, 17-20% chromium, 8-13% nickel, and less than 2% manganese, silicon, and carbon (Keinan et al., 2010; Yilmaz et al., 2012).

The frequent use of preformed crowns for primary tooth restoration has raised the concerns of heavy metals release into oral cavity due to corrosion (Kodaira et al., 2013). Among these leached metals, nickel is known to be a very common cause of contact allergy and hypersensitivity reactions (Keinan et al., 2010; Yilmaz et al., 2012; Kararia et al., 2015).

In an investigation, it was observed that compared to nickel free alloys, stainless steel orthodontic alloys produced greatest damage to cellular DNA (Ortiz et al., 2011). Even nontoxic concentrations of nickel might induce DNA alterations (Anand et al., 2015). Research on orthodontic wires has shown that release of nickel ion increases with decrease in pH (Menek et al., 2012; Milheiro et al., 2012). As discussed earlier, SSCs contains nickel concentration similar to many orthodontic bands and wires (Randall, 2002; Menek et al., 2012).

There are limited numbers of studies available which have evaluated the release of nickel ion from SSCs. Hence present research was conducted to assess nickel ion release from stainless steel crowns of 3M ESPE company at different pH levels.

Materials and Methods:

The present *in vitro* study was carried out in the Department of Pedodontics and Preventive Dentistry, Hitkarini Dental College and Hospital, Jabalpur, Madhya Pradesh in collaboration with Department of Soil Science and Agriculture Chemistry, Jawaharlal Nehru Agriculture University, Jabalpur, Madhya Pradesh. The study was conducted for the period of 15 days. A total of 45 stainless steel crowns for of 3M ESPE (St. Paul, Minnesota, USA/ E5 size) were analysed in the present study.

Artificial saliva samples of pHs 4.3, 5.5 and 6.3 were prepared using an pH electrode. A total of 45 Polyethylene tubes were used for immersion of 45 SSCs in artificial saliva. Three sets of polyethylene tubes were prepared as per three pH levels (30 for each pH). Each polyethylene tube was filled with 5 ml solution of particular pH with one stainless steel crown soaked in it.

Polyethylene tubes were stored at 37°C in an incubator to simulate the oral conditions. After 15 days, crowns from artificial saliva samples were removed and analysis of nickel concentration was performed at Department of Soil Science and Agriculture Chemistry, Jawaharlal Nehru Agriculture University, Jabalpur, Madhya Pradesh using atomic absorption spectrometry (Varian, Agilent Technologies, Santa Clara, USA). Concentration of nickel ion in each sample was recorded in parts per million (ppm).

Statistical Analysis:

Mean and standard deviation (SD) of nickel ion release at different pH levels of artificial saliva was calculated. Further data analysis was performed using one way analysis of variance (ANOVA) followed by LSD (least significant difference) post hoc test and Spearman's rank order correlation. P values <0.05 were accepted as statistically significant. All analyses were performed using SPSS v21.0.

Results:

One way ANOVA showed significant difference ($F=15385.777$, $p<0.001$) for nickel ion release from stainless steel crowns in artificial saliva of pH 4.3, 5.5 and 6.3. LSD post hoc test showed that statistically significant ($p<0.001$) maximum nickel ion release was observed at pH 4.3 followed by pH 5.5 and least nickel ion release was observed at pH 6.3. (Table 1).

Table 1: Comparison of nickel ion release between artificial saliva of pH 4.3, 5.5 and 6.3 in stainless steel crowns.

pH of artificial saliva	Nickel ion release (ppm) in stainless steel crowns	
	Mean ± SD	Min-Max
4.3	0.347 ± 0.003	0.341-0.354
5.5	0.188 ± 0.003	0.183-0.194
6.3	0.135 ± 0.004	0.131-0.143
One way ANOVA	F= 15385.777	
	P= 0.000 (<0.001), Significant difference	
LSD post hoc test	4.3>5.5>6.3	

The correlation showed statistically significant ($P<0.001$) very strong negative relationship ($r = -0.801$) between pH of artificial saliva and nickel ion release from stainless steel crowns (Figure 1).

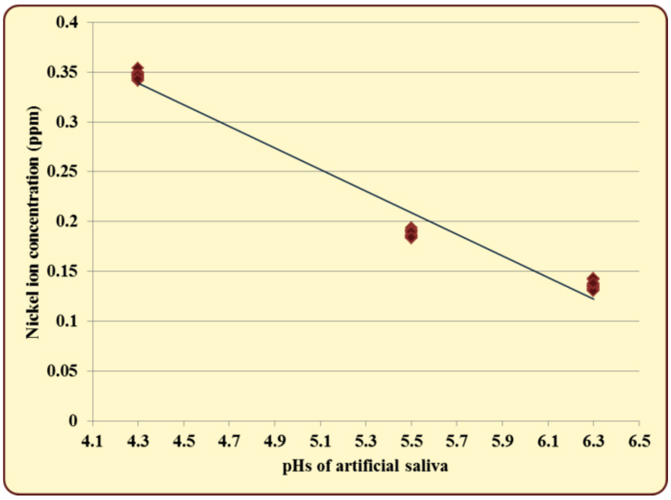

Figure 1: Correlation between pH of artificial saliva (4.3, 5.5 and 6.3) and nickel ion release from stainless steel crowns.

Discussion:

Nickel is integrated in all austenitic stainless steel alloys to stabilize the austenitic phase and to improve tarnish and corrosion resistance. The warm and moist oral aerobic condition offers an ideal environment for corrosion and consequently facilitating the release of metals (Anand et al., 2015).

Nickel sensitivity is common and according to epidemiologic data number of people with sensitivity to nickel has increased to approximately 20% (Keinan et al., 2010; Menezes et al., 2004). Prevalence of nickel hypersensitivity is higher among females than males due to their frequent and constant contact with nickel, since jewellery often contains nickel (Menezes et al., 2004; Ramadan, 2004). Clinical manifestations of nickel allergy in and around oral cavity are burning sensation, erythematous, erosive and lichenoid reactions, stomatitis, gingivitis, labial desquamation and perioral dermatitis (Keinan et al., 2010; Chen et al., 2013).

In the present study pH 4.3 was investigated to simulate a condition that occurs when people consume acidic food (Sfondrini et al., 2010). pH 5.5 is “critical pH” and pH 6.3 is normal pH of human saliva (Hurlbutt et al., 2010).

In present study, maximum nickel ion release was observed at pH 4.3 followed by pH 5.5 and least nickel ion release was observed at pH 6.3 in 3M ESPE crowns. This observation shows that as the pH of artificial saliva was increased, nickel ion release from SSCs decreased.

In an investigation, authors observed more nickel release from stainless steel brackets in pH 4 than in pH 7 solution (Huang et al., 2004). In another experiment, Menek et al. concluded that nickel release from stainless steels crowns was decreased with increasing pH (Menek et al., 2012). Sfondrini et al. observed higher nickel release from orthodontic brackets at lower pH levels (Sfondrini et al., 2010). In an investigation by Milheiro et al., significantly higher amount of nickel release was observed in lactic acid in all orthodontic wire groups. Authors concluded that due to microbiological activity in plaque, patients should be instructed to maintain good oral hygiene (Milheiro et al., 2012). In acidic pH stainless steel oxide film required for corrosion resistance is not stable, which leads to corrosion (Sfondrini et al., 2010).

As reported in the studies, average dietary intake of nickel is 300-500 ppm/day (Sfondrini et al., 2010; Anand et al., 2015). In the present study, in accordance with earlier studies (Bhaskar and Subba Reddy, 2010; Pillai et al., 2013) the measured quantities of released metal ions are minor from a systemic toxicologic viewpoint. However, these levels are sufficient to cause contact allergic reaction (Karnam et al., 2012).

Based on the finding of present research it can be concluded that pH of artificial saliva is inversely related with nickel ion release from stainless steel crowns. With decrease in pH, there is an increase in nickel ion release from stainless steel crowns. Application of results of *in vitro* tests to clinical situation is restricted. Thus, further *in vivo* studies on stainless steel crowns are needed to analyze metal ion release, absorption of released ions and their effects on oral tissues.

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